Remarks

Claims 163-171 (new pending claims) were previously examined as Claims 84-90, 98, and 99, respectively, of United States Patent Application Serial No. 10/036,68, now abandoned ("the '684 Patent Application"), which was a divisional of the '746 Patent Application. At the time of abandonment of the '684 Patent Application, claims 84-90, 98 and 99 stood rejected. The '684 Patent Application Office Action, mailed November 5, 2002, Paper No. 6. This Amendment will address the concerns of the '684 Patent Application Office Action, as they pertain to the claims of the present Application.

I. REJECTION UNDER 35 U.S.C. § 112, ¶2

In the '684 Patent Application Office Action, Examiner Wesley Markham ("Examiner Markham") rejected Claims 170 and 171 of the present Application (Claims 98 and 99, respectively, of the '684 Patent Application) under 35 U.S.C. § 112, ¶2, as being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicant regards as its invention.

Claims 170 & 171. Examiner Markham contended that the use of the term "short" in Claim 170 (from which Claim 171 depends) is a relative term that rendered these claims indefinite. '684 Patent Application Office Action, Paper 6, at 14. Claims 170 and 171 are not indefinite. Applicant respectfully points out that the term "short," as used in Claims 170 and 171 to describe the broken SWNTs protruding from the described surface, is defined in the specification of the present Application. *See* Application, at 25, *ll.* 18-25, which describes short SWNTs as typically being 5-1000 nm in length and preferably from 50-500 nm in length for the purpose of making SWNT template arrays.

II. REJECTION UNDER 35 U.S.C. § 112, ¶1

In the '684 Patent Application Office Action, Examiner Markham rejected Claims 163-169 (Claims 84-90, respectively, in the '684 Patent Application) and Claims 170 and 171 (Claims 98 and 99, respectively, in the '684 Patent Application) under 35 U.S.C. § 112, ¶1, as containing subject matter that was not described in the specification in such a way as to

reasonably convey to one skilled in the relevant art that the inventors, at the time the application was filed, had possession of the claimed invention. '684 Patent Application Office Action, Paper No. 6, at 16.

Claims 163-167, 170 and 171. Examiner Markham contended that the specification, as originally filed, did not have support for the "broad genus of substrate materials comprising SWNTs in general." Support can be found, for example, in the Application, at 4, *ll.* 22-29 and originally filed Claim 36.

Claims 163-167, 170 and 171. Examiner Markham contended that that the specification, as originally filed, did not have support for "using an electric field of any strength to align the nanotubes." Support can be found, for example, in the Application, at 4, *ll.* 22-29 and originally filed Claim 36.

Claims 167 and 171. Examiner Markham contended that the specification, as originally filed, did not have support for "oxidizing temperatures up to about 500°C." Support can be found, for example, in the Application, at 36, *ll.* 21-24 and originally filed Claim 37.

Claim 167. Examiner Markham contended that the specification, as originally filed, did not have support for "oxidizing in either oxygen or carbon dioxide." Support can be found, for example, in the Application, at 36, *ll.* 21-24 and originally filed Claim 37. Claim 167 requires an "atmosphere comprising a gas selected from the group consisting of oxygen, CO_2 and combinations thereof." Applicant notes the disclosure in the Application reflects a combination of both oxygen and CO_2, which is (a) an atmosphere comprising oxygen, (b) an atmosphere comprising CO_2, and (c) an atmosphere comprising a combination of oxygen and CO_2.

Claim 168. Examiner contended that the specification, as originally filed, did not have support for "combing a mat comprising SWNTs with any mechanical device." Support can be found, for example, in the Application, at 36, *l.* 28 – 37, *l.* 3.

Claim 169. Examiner Markham contended that the specification, as originally filed, does not have support for "combing a mat comprising SWNTs with any scanning probe microscope." Support can be found, for example, in the Application, at 36, *l.* 28 – 37, *l.* 3.

III. REJECTION UNDER 35 U.S.C. § 103(a) BASED UPON *FISHBINE*

In the '684 Patent Application Office Action, Examiner Markham rejected Claim 163 (Claim 84 in the '684 Patent Application) under 35 U.S.C. § 103(a) as being unpatentable as obvious based upon *Fishbine* "Carbon Nanotube Alignment and Manipulation Using Electrostatic Fields," *Fullerene Science & Technology*, Vol. 4, No. 1, pp. 87-100, 1996 ("*Fishbine*"). Paper No. 6, at 19.

The basic test for nonobvious subject matter is whether the differences between the subject matter and the prior art are such that claimed subject matter as a whole would not have been obvious to a person having ordinary skill in the art to which a subject matter pertains. *Graham v. John Deere,* 383 U.S.1, 3, 86 S. Ct. 684, 686, 148 U.S.P.Q. 459, 461 (1966). The factual inquiries which must be considered in applying the statutory test: (1) a determination of the scope and contents of the prior art; (2) ascertaining the differences between the prior art and the claims at issue; and (3) resolving the level of ordinary skill in the pertinent art. MPEP § 2131 (citing *Graham v. John Deere Co.).*

A. Determining the Scope and Content of the Prior Art

In determining the scope and content of the prior art, the Examiner must first consider the nature of the problem on which the inventor was working. *See* MPEP § 2141.01. Once this has been established, the Examiner must select, for purposes of comparing and contrasting with the claims at issue, prior art references which are reasonably pertinent to that problem. In selecting references, *hindsight* must be avoided at all costs. *See e.g.* MPEP § 2131 (citing *Hodosh v. Block Drug Co. Inc.,* 786 F.2d 1136,1143 U.S., 229 U.S.P.Q. 183, 189 n.5 (Fed. Cir. 1986).

As pertaining to Claim 163, the claimed invention is for a method of forming an array of single-wall carbon nanotubes by orienting them with an electric field. *Fishbine* presents a primarily theoretical study in which he suggests that "electrostatic alignment of carbon nanotubes *may* be possible." *Fishbine,* at p. 88. Reference to other work involving "Arrays of aligned nanotubes" (*id.*, at p. 87) does not involve electrostatic alignment. *Fishbine's* theoretical work is bolstered by experimental work involving Thornel® graphite fiber rods—which are suggested to be "nanotube analogs" (*id.,* at p. 90)—suspended in various dielectric

liquids. Thus, while these *may* approximate multi-wall carbon nanotubes (which are far more rigid than single-wall carbon nanotubes), analogies to single-wall carbon nanotubes are highly speculative as single-wall carbon nanotubes have dimensions that are approximately three orders of magnitude smaller than the Thornel rods, and because SWNTs lack the rigidity of the Thornel rods.

The basis of *Fishbine's* work is the physical phenomenon by which electrostatic fields are known to induce dipole moments in conducting objects whose dielectric constant differs from that of the surrounding medium. *Fishbine* merely assumes that carbon nanotubes will behave this way, but does not teach how to implement this concept for use with carbon nanotubes, *i.e.*, how to identify and separate conducting nanotubes, how to disperse them in liquid media, etc. While *Fishbine* never explicitly differentiates between multi- and single-wall carbon nanotubes, this reference mentions theoretical conductivity predictions for multi-wall carbon nanotubes. *Fishbine*, at p. 91. Furthermore, it would have been apparent to those skilled in the art that multi-wall carbon nanotubes were the nanotubes *Fishbine* envisioned aligning. This is highly noteworthy because multi- and single-wall carbon nanotubes behave quite differently due to differences in rigidity, dimensions and aspect ratios, conductivity, polarizability, uniformity, etc. Thus, while *Fishbine* identifies electrostatic fields as a possible mechanism for the alignment of carbon nanotubes, it does no teach this process.

B. Differences Between Prior Art and the Claim

In ascertaining the differences between the cited prior art and the claim at issue, the Examiner must evaluate the claimed subject matter as a whole; there is no requirement that the differences themselves be nonobvious. MPEP § 2141.02. The requisite view of the whole invention mandates consideration of not only its structure, but also of its properties and the problems solved. *See* MPEP § 2141.02. Further, the mere fact that the prior art can be modified does not make the modification obvious unless the prior art suggests the desirability of the modification; there must be some logical reason apparent from positive, concrete evidence that justifies the modification. *See* MPEP § 2143.0 1.

As stated above, *Fishbine* fails to teach a method of aligning carbon nanotubes in general, much less a method for doing so with single-wall carbon nanotubes. *Fishbine* merely

draws analogies between Thornel® graphite fiber rods, which can be oriented in solution with an electric field. This is a weak analogy to single-wall carbon nanotubes due to the tremendous differences in size, aspect ratios, conductivity, polarizability, rigidity, etc. Furthermore, *Fishbine* does not teach how to remove the supposedly analogous Thornel® rods from the liquid media in which they were dispersed so as to form an array. Thus, *Fishbine* teaches neither the alignment of single-wall carbon nanotubes, nor the formation of an array of any sort.

Claim 163 specifically points out a method for making an array of single-wall carbon nanotubes by applying an electric field to the surface of a material comprising single-wall carbon nanotubes.

C. Ordinary Skill and Relevant Art

In resolving the level of ordinary skill in the pertinent art, the Examiner must step backward in time and into the shoes worn by a person of ordinary skill when the invention was unknown and just before it was made. The hypothetical person skilled in the art can summarily be described as one who thinks along lines of conventional wisdom in the art and neither one who undertakes to innovate nor *one who has the benefit of hindsight. See e.g. Standard Oil Co. v. American Cynamid Co.,* 774 F.2d 448, 454, 227 U.S.P.Q. 293, 298 (Fed. Cir. 1985). Thus, neither an examiner, nor a judge, nor a genius in the art at hand, nor even the inventor is such a person skilled in the art. *See* MPEP § 2143.03.

As has been established above, *Fishbine* fails to teach the formation of carbon nanotube arrays by alignment in electrostatic fields. *Fishbine* merely suggests that carbon nanotubes *might* be aligned in electrostatic fields. This suggestion, coupled with a knowledge of the state of the art at the time Applicants filed their original patent application, would not have rendered the invention as described in Claim 163 (in the original or amended form) obvious to a person of ordinary skill in the art. As an example of this, it was not obvious from *Fishbine* that such an alignment of carbon nanotubes might be achieved in the *absence* of a suspending medium.

Claim 163 is not obvious in view of *Fishbine.*

IV. REJECTION UNDER 35 U.S.C. § 103(a) BASED UPON *FISHBINE* IN VIEW OF EITHER *EBBESEN* OR *UCHIDA*

In the '684 Patent Application Office Action, Examiner Markham rejected Claims 164-166 and 170 (Claims 85-87 and 98, respectively, in the '684 Patent Application) under 35 U.S.C. § 103(a) as being unpatentable as obvious based upon *Fishbine* in view of either United States Patent No. 5,641,466, issued to Ebbesen, *et al.* ("*Ebbesen*") or United States Patent No. 5,560,898, issued to Uchida, *et al* ("*Uchida*"). '684 Patent Application Office Action, Paper No. 6, at 21.

Claim 164. In evaluating Claim 164 (Claim 85 in the '684 Patent Application), Applicant refers the Examiner to the discussion above pertaining to Claim 163 (from which Claim 164 depends). Claim 164 further limits Claim 163 by providing for a step by which the purified bucky paper surface is subjected to oxidizing conditions so as to facilitate the alignment of the single-wall carbon nanotubes on the surface. In determining the scope and content of the prior art as pertaining to Claim 164, Applicant again asserts that *Fishbine* fails to teach a method for actually making an array of aligned carbon nanotubes (multi- or single-wall).

Fishbine is merely a highly speculative theoretical work. Reference in *Fishbine* to arrays of aligned nanotubes as cold-field-emission electron sources (*Fishbine*, at p. 87) involves techniques other than electrostatic alignment. *Ebbesen* and *Uchida* teach an oxidation of multi-wall carbon nanotubes for the purpose of purification only, not for the purpose of facilitating alignment in electric fields. Claim 164, as dependent from amended Claim 163, already possesses purified single-wall carbon nanotubes prior to the alignment process. Thus, the combination of *Fishbine* with either *Ebbesen* or *Uchida* fails to teach all of the elements in Claim 164.

Many of the differences between the claimed subject matter and the prior art have already been addressed above. Aside from the differences in scope, perhaps the most striking difference is the prior art's use of multi-wall carbon nanotubes. Analogies between multi-wall carbon nanotubes and single-wall carbon nanotubes are not substantial, as these materials are fundamentally different in their electrical, physical, mechanical and chemical properties.

By combining *Fishbine* with either *Ebbesen* or *Uchida*, Examiner Markham was attempting to establish a prima facie case of obviousness. To do this, however, it is necessary for the Examiner to present evidence, of a motivation or suggestion to modify or combine the references to make the claimed invention. MPEP § 2142. The suggestion or motivation must be found in one of three sources: the references themselves, the nature of the problem to be solved, or the knowledge of persons of ordinary skill in the art. MPEP § 2143.01 (citing *In re Rouffet,* 149 F.3d 1350, 1357 47 U.S.P.Q.2d 1453, 1457-58 (Fed. Cir. 1998)). And there must be evidence of an expectation of success. MPEP § 2142.

All previously mentioned shortcomings of *Fishbine* aside, there is no suggestion in *Fishbine* that either an oxidative treatment, or any purification step, would facilitate the electrostatic alignment of carbon nanotubes (of any type), or their alignment into arrays. Likewise, there is no suggestion in either *Ebbesen* or *Uchida* that their purification processes would facilitate such electrostatic alignment of carbon nanotubes (of any type).

The purification processes described in *Ebbesen* and *Uchida* involve arc-grown multi-wall carbon nanotubes. Purification of single-wall carbon nanotubes is quite different for two reasons: (a) production of single-wall carbon nanotubes requires metal catalyst particles that cannot be removed via subsequent oxidation treatments (they would merely form refractory metal oxide particles, or metal particles with metal oxide overcoats); and (b) having only one layer of highly strained sp^2 carbon makes single-wall carbon nanotubes much more reactive to oxidative species. In fact, subsequent work has shown that under relatively mild conditions, oxidative agents can "cut" the single-wall carbon nanotubes into shorter segments (*Liu* et al., "Fullerene Pipes," *Science*, Vol. 280, pp. 1253-1256, 1998). In hindsight, as recent scanning tunneling microscopy studies have revealed much about defects along the sidewalls of the single-wall carbon nanotubes, it is likely that this cutting process is responsible for the increased ability to align the single-wall carbon nanotubes in an electric field. It would not, however, have been obvious to one of ordinary skill in the art at the time the Application was made. Obviousness rejections must rest clearly on a factual basis, and that these facts must be interpreted without hindsight reconstruction of the invention from prior art.

Claims 165 & 166. In evaluating Claims 165 and 166 (Claims 86 and 87, respectively, in the '684 Patent Application), Applicant refers the Examiner to arguments for Claims 163 and 164 (from which Claims 165 and 166 depend) above. Additionally, the scope of the prior art has already been addressed.

Examiner Markham asserted *Fishbine* taught the further limitation of "coalescing" the single-wall carbon nanotubes, as described in Claim 165. *Fishbine*, however, merely teaches that large graphite fiber "analogs" can be oriented in electrostatic fields, and are subject to "clumping" (p. 90), without specifying what a "clump" is. All references to arrays or surfaces involve previous work not involving electric fields. Furthermore, Examiner Markham was incorrect when asserting that arrays of aligned nanotubes are synonymous with coalesced nanotubes. Nanotubes can be "coalesced" in either ordered, or disordered arrangements. And "arrays," being ordered arrangements, may, or may not be coalesced.

As described above, the chemical oxidation mentioned in Claim 166 is for the purpose of facilitating alignment of single-wall carbon nanotubes in an electric field for the purpose of forming an array of single-wall carbon nanotubes. For the same reasons outlined for Claim 164, it would not have been obvious to a person of ordinary skill in the art to oxidize single-wall carbon nanotubes in the manner of *Ebbesen* or *Uchida* for the purposes of facilitating alignment in an electric field. In fact, such a processing step would be counter-intuitive based on the fact that such purification techniques cannot be translated to single-wall carbon nanotubes by virtue of the fact that they cannot rid the material of the metal catalysts used to grow the single-wall carbon nanotubes. Single-wall carbon nanotubes must be purified with alternative procedures.

Claim 170. In evaluating the scope and relevance of the prior art documents, the Examiner is referred to the previous arguments above. The invention as described in Claim 170 (Claim 98 in the '684 Patent Application) differs from the prior art in many ways. Again, *Fishbine* does not teach using an electric field to form arrays of aligned carbon nanotubes. Reference in *Fishbine* to "arrays of aligned nanotubes" (*Fishbine*, at p. 87) involve techniques other than electrostatic alignment. Furthermore, such an array is made of multi-wall carbon nanotubes, not the single-wall carbon nanotubes of Claim 170 which can be expected to behave

quite differently. *Fishbine* itself merely teaches the alignment of "nanotube analogs" in various liquid media using electric fields. Any reference in *Fishbine* to aligning carbon nanotubes using electric fields is merely of a speculative nature.

Furthermore, *Ebbesen* and *Uchida* disclose multi-wall carbon nanotube purification processes. The purified single-wall carbon nanotubes described in Claim 170 have, by necessity (*see* above), been purified by an entirely different technique than disclosed in either of these two references. (*See* Application, at 21-24). Single-wall carbon nanotubes differ markedly from multi-wall carbon nanotubes in the manner in which they respond to oxidizing agents. Single-wall carbon nanotubes can be "cut" at their defect sites, and it is this cutting process that likely facilitates the alignment in electric fields. Multi-wall carbon nanotubes have not, to date, been reported to have been cut by such processes.

Claims 164-166 are not obvious based on *Fishbine* in view of either *Ebbesen* or *Uchida*.

V. REJECTION UNDER 35 U.S.C. § 103(a) BASED UPON *FISHBINE* IN VIEW OF *UCHIDA*

In the '684 Patent Application Office Action, the Examiner rejected Claim 167 (Claim 88 in the '684 Patent Application) under 35 U.S.C. § 103(a) as being unpatentable as obvious based upon *Fishbine* in view of *Uchida*. '684 Patent Application Office Action, Paper No. 6, at 25.

The scope of the cited prior art has already been addressed. The differences between Claims 163-164 (from which Claim 167 depends) and the cited prior art have already been addressed. Claim 167 describes the method of Claim 164 with the further limitation that the single-wall carbon nanotube surface is heated "to a temperature up to 500°C in an atmosphere comprising a gas selected from the group consisting of oxygen, CO_2, and combinations thereof." While *Uchida* teaches the purification of multi-wall carbon nanotubes in an oxygen-containing atmosphere at temperatures that include 500°C, this doesn't change the fact that (a) this was done in order purify multi-wall carbon nanotubes, (b) the single-wall carbon nanotubes of Claim 167 are already purified, and (c) there is no suggestion in the prior art that such an oxidation would facilitate the alignment of single-wall carbon nanotubes in an electric field.

Claim 167 is not obvious in view of *Fishbine* in view of *Uchida*.

VI. REJECTION UNDER 35 U.S.C. § 103(a) BASED UPON *FISHBINE* IN VIEW OF *EBBESEN* AND *UCHIDA*

In the '684 Patent Application Office Action, Examiner Markham rejected Claim 171 (Claim 99 in the '684 Patent Application) under 35 U.S.C. § 103(a) as being unpatentable as obvious based upon *Fishbine* in view *Ebbesen* and *Uchida*. '684 Patent Application Office Action, Paper No. 6, at 27.

The scope of the cited prior art has already been addressed. The differences between Claim 170 (from which Claim 171 depends) and the cited prior art have also been addressed previously. Examiner contends that all of the limitations described in Claim 170, plus the additional limitations of "heating the surface up to about 500 °C in an atmosphere of oxygen and CO_2," as described in Claim 171 are rendered obvious over *Fishbine* in view of *Ebbesen* and *Uchida*. The Examiner is requested to refer back to arguments made in favor of Claim 170 above. The Examiner is further requested to note that an "atmosphere of oxygen and CO_2," as described in Claim 171, would not be considered by those of skill in the art to be "air" ('684 Patent Application Office Action, Paper No. 6, Page 14, lines 2-3). Terrestrial air is primarily comprised of nitrogen and oxygen with only very small amounts (~ 300 ppm) of CO_2.

Claim 171 is not obvious based on *Fishbine* in view of *Ebbesen* and *Uchida*.

VII. REJECTION UNDER 35 U.S.C. § 103(a) BASED UPON *GE* IN VIEW OF *HENDERSON*

In the '684 Patent Application Office Action, Examiner Markham rejected Claims 168 and 169 (Claims 89 and 90, respectively, in the '684 Patent Application) under 35 U.S.C. § 103(a) as being unpatentable as obvious based upon Ge, *et al.* ("Scanning Tunneling Microscopy of Single-Shell Nanotubes of Carbon," *Appl. Phys. Lett.*, Vol. 65, No. 18, pp. 2284-2286, 1994) ("*Ge*") in view of United States Patent No. 5,935,339, issued to Henderson, *et al.* ("*Henderson*"). '684 Patent Application Office Action, Paper no. 6, at 28. In terms of the scope of the prior art, *Ge* teaches the condensation of small amounts of nanotubes, and other nanostructures formed at low pressures, onto the surface of freshly-cleaved highly-ordered pyrolytic graphite (HOPG) for the purpose of imaging them under high vacuum with a

scanning tunneling microscope. *Ge* does not teach scanning a mat of single-wall carbon nanotubes with a scanning tunneling microscope, as the Examiner asserts. *Henderson* teaches a method of decontaminating a surface (such as a scanning probe microscope tip) with oxygen radicals and/or ozone. *Henderson* further teaches that as scanning probe microscopes image a surface, the probe tips will invariably pick up debris that will negatively affect the imaging process. Such a decontamination process is meant to alleviate this problem. Neither *Ge* nor *Henderson* teach combing a mat of single-wall carbon nanotubes.

Examiner Markham indicated *Henderson* taught "probes used in STM touch the surface of the sample as the microscope scans the sample." (*Henderson*, col. 1, *ll.* 14-23). *Henderson* does not teach using an STM to touch the surface of the sample, unlike an atomic force microscopy (AFM) that does do so during the imaging process. In scanning tunneling microscopy (STM), any contact between the probe tip and the surface is undesired. The mechanism by which STM operates requires that there be a gap between the tip and the surface and that there be an electric potential applied between said tip and said surface. Electrons can then "tunnel" through this "barrier" establishing a small tunneling current. Physical contact between probe tip and surface destroys this tunneling current.

With regard to the nature of STM, as outlined above, it would not have been obvious to a person of ordinary skill in the art to "comb" the surface of a mat of single-wall carbon nanotubes (or any surface for that matter) to generate an array of single-wall carbon nanotubes because contact of the probe tip and surface are not part of the normal operation of an STM. In normal operational use, the STM is used to image surfaces, not manipulate them.

With regard to AFM (where the probe tip actually comes into contact with the surface during the imaging process), like STM normal operating procedures for AFM use are designed for imaging purposes. The force applied to the probe tip is very small and must preclude forces sufficient to cause translation of objects on the surface, otherwise an image could not be obtained. Thus, as in the case with STM, it would not have been obvious to one of ordinary skill in the art to use an AFM comb a mat of single-wall carbon nanotubes for the purpose of generating an array of said nanotubes.

Furthermore, since *Ge* does not teach "combing a mat" of single-wall carbon nanotubes with an STM probe (*Ge* teaches *imaging* a surface on which a small population of single-wall carbon nanotubes and other nanostructures have been condensed), it would not have been obvious to a person of ordinary skill in the art to use a scanning probe microscope (of any kind) to comb a mat of single-wall carbon nanotubes for the purpose of forming an array. Even if *Ge* did teach such a combing process, and even if *Ge* did teach applying this process to a mat of single-wall carbon nanotubes, there is nothing in *Ge* or *Henderson* to suggest that an array of single-wall carbon nanotubes could be generated by doing so.

Claims 168 and 169 are not obvious based on *Ge* in view of *Henderson*.

Conclusion

As a result of the foregoing, it is asserted by Applicant that the Claims in the present Application are in a condition for allowance, and respectfully requests an early allowance of such Claims.

Applicant believes that no further fees are due. However, the Director is Authorized to debit any amounts due by this paper to Deposit Account No. 23-2426 of Winstead Sechrest & Minick P.C.

Applicant respectfully requests that Applicant's attorney be called at the below listed number if should there be any questions related to this matter.

Respectfully submitted,
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